Design for Manufacturability

WHEELER
CircuitRunners

What is Design for Manufacturability?

- Design around what you can fabricate
- Thinking through the entire fabrication process
- Using elements of fabrication to aid design

How do we fabricate parts?

There are two different ways we fabricate parts:

CNC and Manual Fabrication

CNC Machining

- Computer Numerical Control
- Precise
- Fast
- Expensive

Manual Fabrication

- Humans using tools
- Requires Shop Training
- Can be Fast
- Has more applications than CNC

Try to utilize CNC Machining as much as possible up front to make manual fabrication easier.

CNC Machines We Use

*There’s a lot more of them we don’t utilize

Waterjet Cutting

- Uses high-powered water and sand mixture
- Allows for precision cut parts
- Useful for sheet metals (aluminum, steel)
- Thiccnesses 1/16” - ⅛” are free to GA teams
- Tolerance of +/- 1/32”

CNC Router

- Metal cutting bit spun at high speeds to cut through material
- Allows for precision cut parts when programmed correctly
- Useful for wood and polycarbonate
- Helpful with making prototypes
- Can machine up to ¾” Material

3D Printing

- Non-traditional manufacturing
- Additive
- Weight and Strength are tradeoffs
- Used for lightweight mounts mostly
- Only can create plastic parts

Things to be mindful of when CNC Machining

- CNC Machines hate sharp corners
- Complex and repeated hole patterns will trip up a machine
- Turnaround Times can be lengthy
- CNC Machines can break, causing delays
- Proper CAD Geometry is critical

Manual Fabrication Equipment We Use

Sheet Metal Brake

- Used to fold sheet metal parts
- Cannot form a opposing fold coincident to an existing flange
- Flanges must be precisely placed
- Has a minimum flange length

Mitre Saw

- Used to cut stock to length
- Can make angled cuts up to 60°
- Saw Blades are made for specific materials
- Provides a clean cut

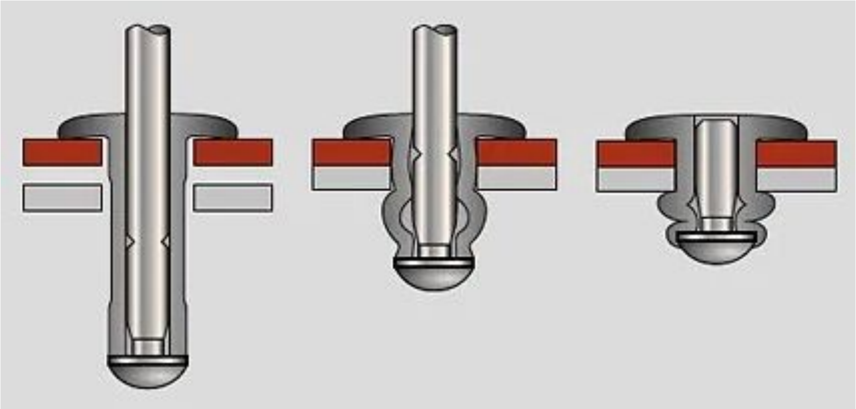
Drill Press

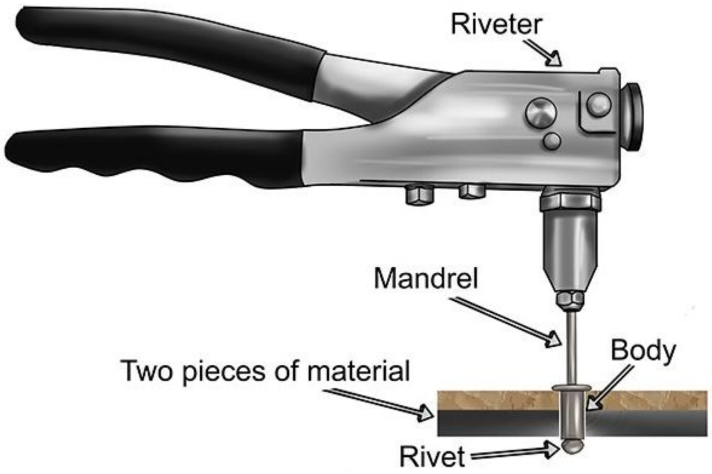
- Used to create holes in material
- Useful to drill through multiple faces of material
- Has multiple speeds for different materials
- Very easy to use

How do we fasten parts together?

Rivets

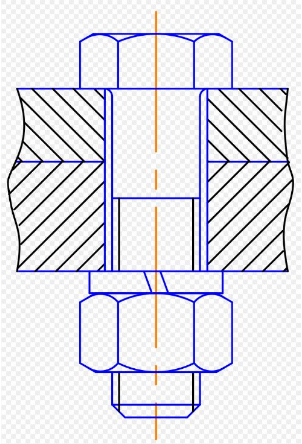
- Semi-Permanent connection
- Lighter weight than nuts and bolts
- Only need one side of access to connect
- Weaker than nuts and bolts
- **CR STANDARD: 3/16” ONLY**





Bolts, Screws, Nuts

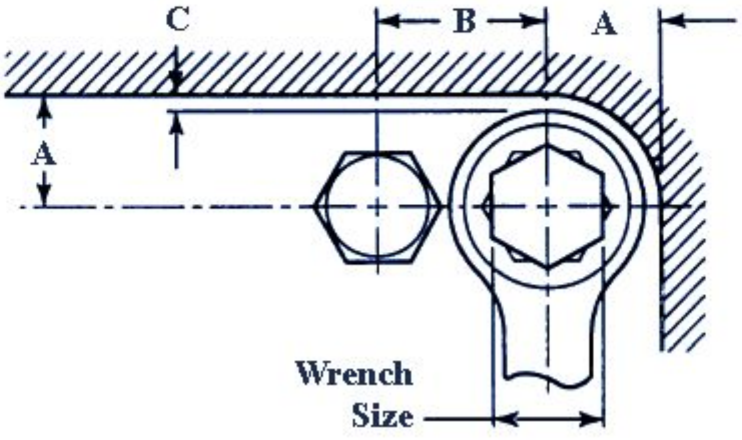
- Used for parts that may need to be replaced
- Can be unscrewed relatively easily
- Locking mechanisms exist to combat vibration loosening
- Need access to both sides
- Can also fit into a tapped hole
- Stronger than a riveted connection
- Come in various diameters to fit into holes of different sizes
- **CR STANDARDS: ¼-20, #10-32, and Motor Screw Sizes**

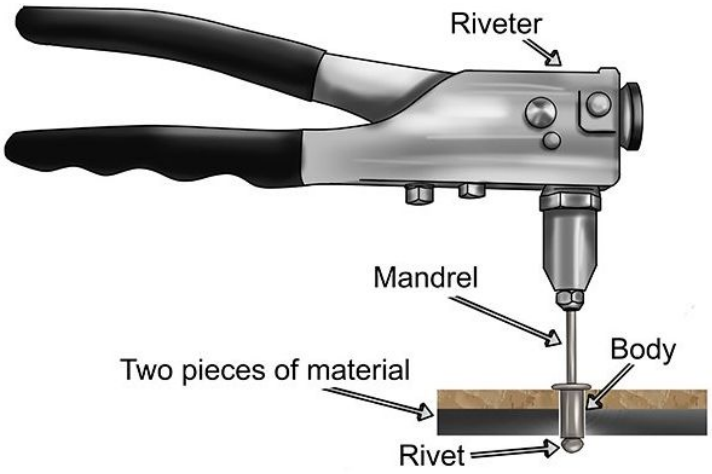


Welding

Tool Clearance

- Installation is critical for final robot assembly
- Ensure there is room to fit tools to tighten or fasten parts
- Make largest structural connections external





Real World Example

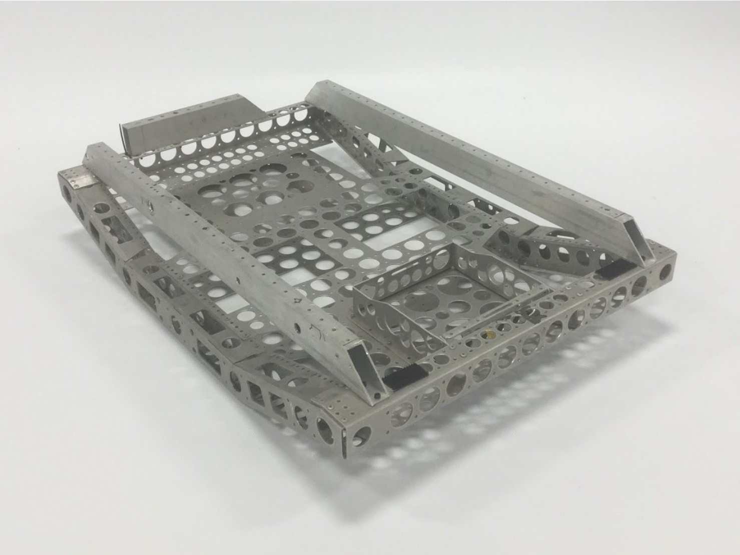
- Bolt clearance was not thought through during engineering.
- Resulted in around $2500 in rework
- Delayed Installation by 2 Weeks
- Resulted in a fine by GC of $1250
- Total Cost : Circa $5000 total, 32 Man Hours *and degradation of my morale*
- That was to change 16 Holes

TOOL CLEARANCE IS CRITICAL TO KEEPING PROJECTS GOING

Headache Free Sheet Metal Design

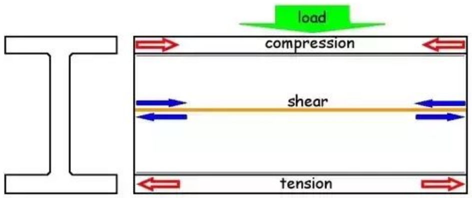
Basics of Sheet Metal

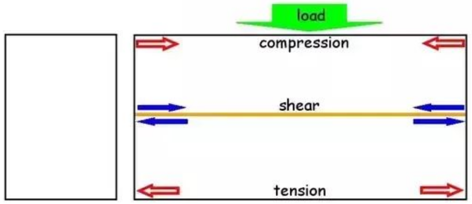
- Sheet Metal has Strengths
  - Custom Solutions
  - Strong when used properly
  - Lightweight
- Sheet Metal has Weaknesses
  - Heavy Dependence on CAD
  - Flanges must be precise
  - Requires more forethought than other solutions



Flanges

- Bends in metal along edges
  - Increase Structural Integrity
    - Metal is strongest in tension
  - Add mounting holes
- Created with Sheet Metal Brake
  - Break lines must be placed precisely
  - Minimum length for flanges
  - Maximum of 80° Bend (10° past 90)

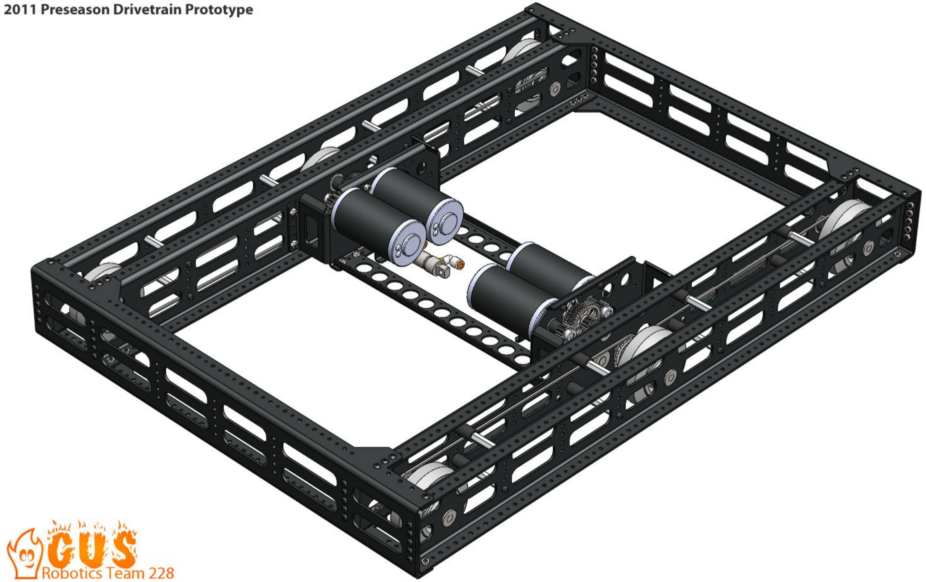




Flanges Cont.

- Flange Design is limited by manufacturing capabilities
- Sheet Metal Brake Limitations
  - Maximum Flange Length - 4’
  - Maximum Flange Depth - Infinite
  - Maximum Gauge Available - 1/8th Inch
  - No Bi-Directional Flanging
  - Tooth Removal Capable

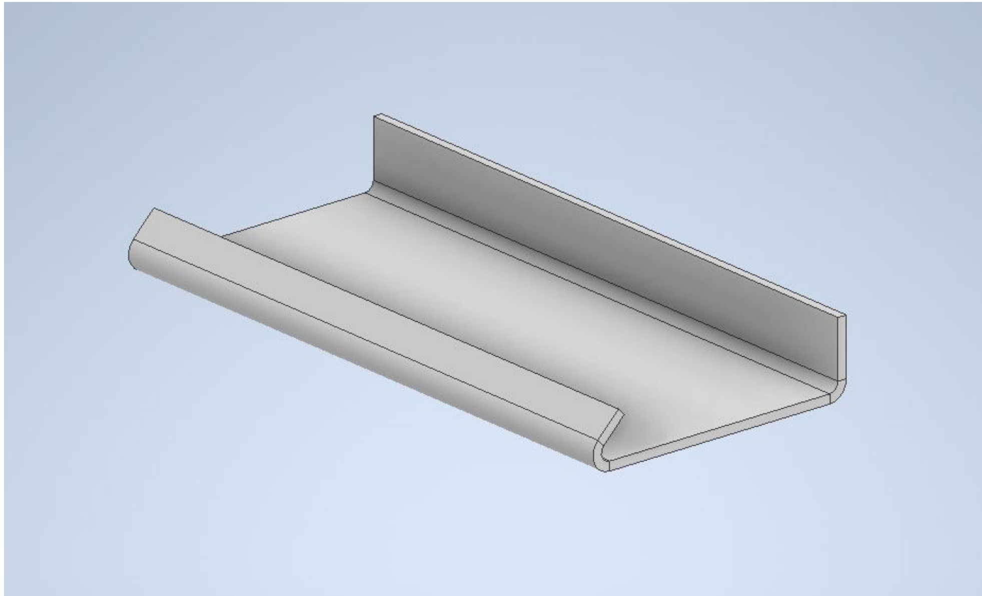
2011 Preseason Drivetrain Prototype




JET

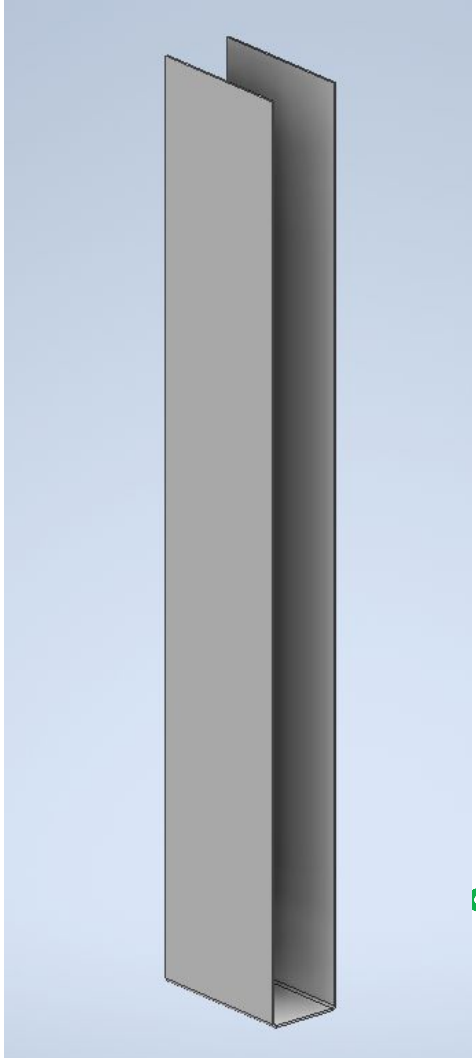
Incorrect Sheet Metal Design

- Flange is past 80 degrees
    - Overflanged, Resulting in collision with brake teeth
- Possible fixes
    - Redesign applicable parts
    - Make a bridge piece



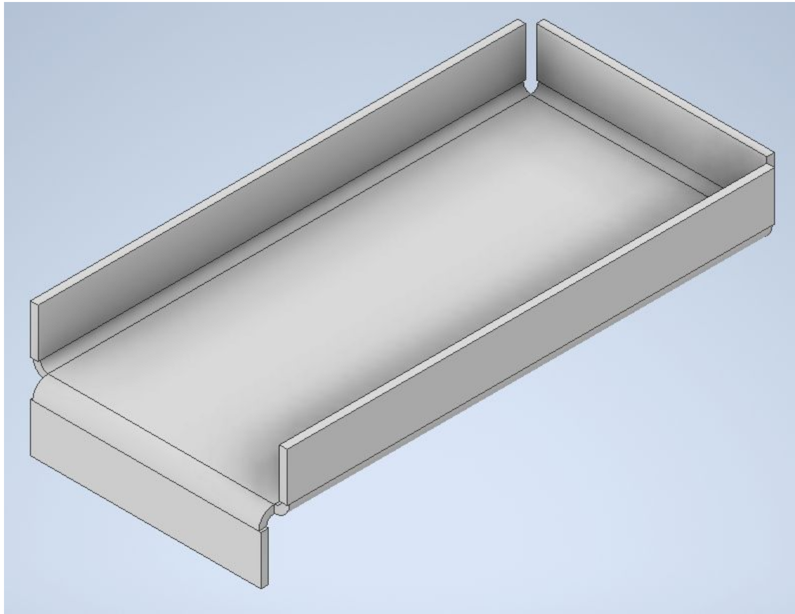
Incorrect Sheet Metal Design

- Flanges too close together
  - Results in collision with brake teeth
- Possible Fixes
  - Make two separate pieces with one flange each
  - Mount two separate pieces together



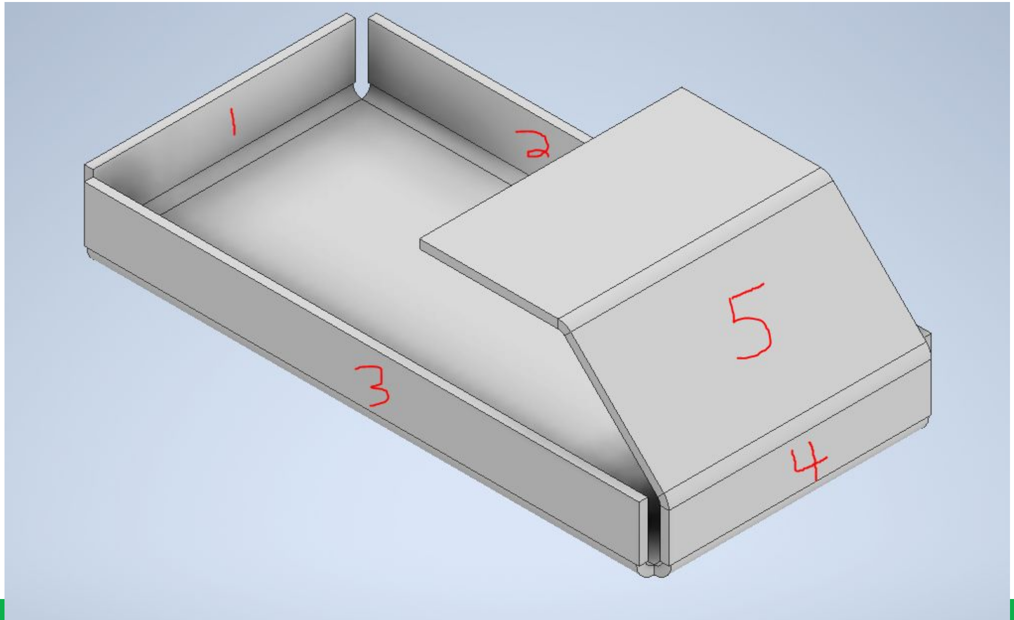
Incorrect Sheet Metal Design

- Opposed Flange Coincident
  - Sheet Metal Brake would damage existing Bends upon opposed bend
- Possible Fixes
  - Connector Piece to Create a bi-directional flange



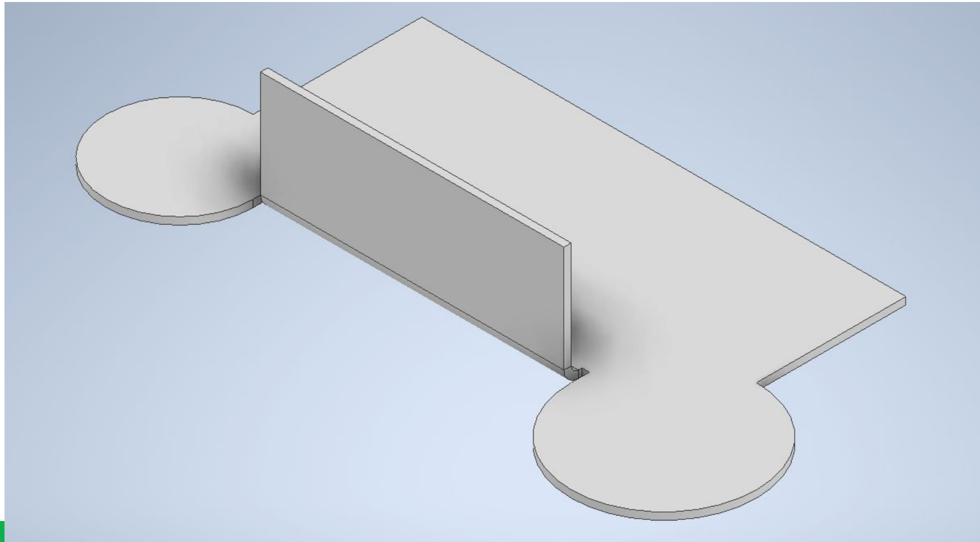
Flange Fabrication Ordering

- Flange Order Matters
- If flanged in incorrect order, you will have to recut parts



Incorrect Sheet Metal Design

- Interior Flanging
  - Entire Edges must be flanged, not sections of them
  - Resulting Bend would have both circles in it
- Possible Solutions
  - Create additional part for connection



How do we get sheet metal cut?

KSU + GA First partnership

- We can use KSU's water jet machine to cut out aluminum for FREE!
- If a thicker gauge of aluminum is needed, buy your own.
- Follow instructions on this website
- Email edbarker@kennesaw.edu

The material is aluminum, 5xxx series, heat treatable, and cold formable.
The size of the donated material is:

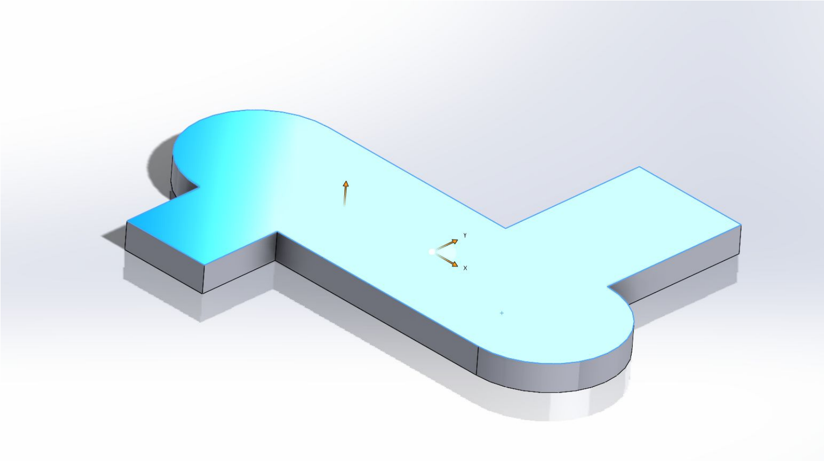
0.063 (actual gauge 0.061) 60" length 60" width
0.090 (actual gauge 0.084) 60" length 60" width
0.125 (actual gauge 0.122) 60" length 60" width

How to get File Formats? (Solidworks)

Include the **.STEP file** of the part AND the 2D view of the part in **.DWG** format

- The part must be manufacturable in 2D, so it does not matter if you use the sheet metal feature or just extrude the sketch, as long as it is one face.
- Right click on the **face** of the object and click "export to DXF/DWG" and change to DWG to get a 2D sketch of the face
- Save the part as .step using "Save as"

Note: Water jets are pretty bad with small, jagged edges so be mindful in your design



Selected: Object face to be waterjet

Lathing

What is a lathe?

- Used to create cuts concentric to axis of rotation
    - Grooves for E-Rings
    - Create a smaller diameter shaft
    - Cut threads into metal
    - Create custom precise round objects
- Cannot make sided geometry
- Used primarily for retaining rings and reduction of shaft ends

In Review…

DFM Rules

- CNC and CAD as much as possible
- Think about tooling throughout your design process
- Allow for Tool Clearance through designs, specifically for parts that are failure points such as motors and breakers
- Utilize Sheet Metal to create structurally strong, but lightweight custom solutions to problems
- Incorporate specificity into your designs as to fabrication techniques

At the end of the day, make it easier on yourself. You will be building it.